

APPARATUS AND METHOD FOR MEASURING CHROMATIC DISPERSION BY VARIABLE WAVELENGTH

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SPECIFICATION
CROSS REFERENCE TO RELATED APPLICATIONS
FIELD OF THE INVENTION
[Technical Field]

The present invention relates to an apparatus for
5 measuring Chromatic Dispersion (CD) in optical fibres, and to
the related method.

BACKGROUND OF THE INVENTION

Chromatic dispersion is a particularly important
characteristic of optical fibres due to the distortion
effects it causes on the optical signals that propagate in
10 fibres for telecommunications.

Such a phenomenon is, as is well known, linked to the
different group velocities with which various spectral
components of optical signals propagate in a fibre, for
instance between an optical transmitter and receiver or a
15 first and a second end of the fibre.

The spectral components of an optical signal, due to the
different group velocities, reach the receiver at different
times and determine a distortion of the received signal both
in analogue transmission systems, and in digital transmission
20 systems.

The chromatic dispersion of optical fibres, as is well known,
is determined mainly by two factors, the dispersion
characteristics of the material whereof the fibres are made
(dependence of the refractive index of the material on
25 frequency), and the very nature of the propagation of an
optical signal in a waveguide (the so-called "waveguide
dispersion").

The chromatic dispersion of optical fibres can be suitably
controlled by a careful design of the profile of the
refractive index of the fibres. In fact, today, optical fibres
30 are manufactured with chromatic dispersion characteristics
specifically studied to meet the requirements of the most
sophisticated optical transmission systems.

As ~~these~~ ^{said} requirements become ever more stringent, in particular for transmission systems with bit rates of 10 Gbit/s or higher, the need also increases to "characterize" the CD of the optical fibres with accuracy, not only in the factory during the product qualification stage, but also in field, for new or less recently installed systems.

~~Such~~ ^{said} "characterization" is indispensable in order to design and install new-generation transmission systems (with bit rates of 10 Gbit/s or higher) on recent fibres or to verify, in case of less recent systems, the possibility of supporting a higher transmission capacity.

(Background Art)

Today, the chromatic dispersion of optical fibres is measured by means of at least three different, consolidated techniques, as described, for instance, in the ITU-T Recommendation G.650. Amongst such techniques, one of the most commonly used is the so-called Phase Shift (or PS) technique. It consists of measuring the phase shift introduced by the optical fibre segment being measured on a sinusoidal signal that modulates an optical carrier which is made to propagate in the fibre itself. The measurement is repeated at different wavelengths of the aforesaid optical carrier and for each of them the group delay of the modulating sinusoidal signal, which is proportional to the aforesaid phase shift, is calculated.

An ~~embodiment~~ ^{embodiment} of an apparatus or instrument for measuring chromatic dispersion is, for instance, described in US Patent 6,313,934.

This document describes, inter alia, a methodology for measuring chromatic dispersion wherein the phase shift of the sinusoidal signal, that modulates the optical carrier, introduced by the fibre segment is measured by synchronising, by means of absolute timing systems obtained from a GPS (Global Positioning System), appropriate devices for

generating and measuring the sinusoidal signal, positioned at the ends of the fibre itself.

The prior art method entails the need to simultaneously access the two ends of the fibre to be characterised, to apply appropriate instrumentation to the two ends of the fibre and to use an absolute reference system with which to synchronise the instrumentation at the two ends of the fibre.

Disclosure of the Invention **OBJECT OF THE INVENTION**
It is the object to provide
 Object of the present invention is a measuring apparatus

and related method that does not necessarily require *(to)* access the two ends of the fibre in order to perform *(the)* chromatic dispersion measurements, nor require *(to use)* an absolute reference system to synchronise the instrumentation.

SUMMARY OF THE INVENTION
 This object is achieved by the apparatus for measuring the chromatic dispersion of optical fibres and the corresponding method as claimed.

Insert "A" → therefore
 In particular, the object is achieved by the apparatus that allows to characterise or measure the chromatic dispersion or CD of a fibre segment accessing only one end of the fibre itself.

According to another characteristic of the present invention, the apparatus does not require *an* absolute external reference signal, but has within it all that is necessary to determine the chromatic dispersion of the fibre being measured.

Fe Brief Description of *Drawings*

This and other characteristics of the present invention shall become readily apparent from the following description of a preferred embodiment, *given* purely by way of non limiting example] with the aid of the accompanying drawings, in which:
 Fig. 1 shows a block diagram of the apparatus for measuring chromatic dispersion according to the invention; and
 Fig. 2 shows an example of impulsive signal used in the apparatus of Fig. 1 to measure chromatic dispersion.

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SPECIFIC DESCRIPTION

[Best mode for Carrying Out the Invention]

With reference to Fig. 1, the apparatus or instrument 10, according to the invention, comprises a tuneable source of optical signals (optical source) 11, a device for generating modulating pulses (signal generator) 12 able to modulate the optical signals generated by the optical source 11, by means of a modulator or multiplier device 19, and a coupling device 15 able to convey the modulated optical signal on an optical fibre 50 to be subjected to characterisation or analysis.

The apparatus 10 further comprises a phase comparator 14 connected at the output of an optical receiver 16 and a control processor (processor) 18 connected by means of respective control wires (shown in the figure with dashed lines) to the optical source 11, to the signal generator 12, to the phase comparator 14 and to the optical receiver 16.

The apparatus 10 is connected, by means of the coupling device 15, to a first termination of the fibre (fibre segment) 50 in correspondence with the end adjacent to the apparatus.

According to the present embodiment, the fibre segment 50 to be characterised or measured has in correspondence with the second end, in general far from the apparatus 10, a reflecting termination 51, of a known kind, constituted, for example, by a reflecting optical component, specifically connected to the end of the optical fibre to perform the characterisation, or, preferably, by a not-angled terminal connector.

The optical source 11 of the apparatus 10, known in itself, is able to generate optical signals at variable wavelength, based on commands transmitted by the processor 18 through the respective control wire and to transmit them to the modulator device (modulator) 19 to be modulated with the modulating pulses.

The signal generator 12 comprises a generator of sinusoidal signals (sinusoidal generator) 23, a generator of impulse signals (impulse generator) 24 and an associated multiplier device 29, known in themselves, and is able to generate the product of the aforesaid sinusoidal signal and of the impulse signal and to send them to the modulator 19 as modulation signals of the kind shown by way of example in Figure 2.

In particular, the modulation signals (modulating) are shaped by pulses of determined duration and periodicity in which the pulses themselves have their amplitude variable in sinusoidal fashion about a reference level.

Both the sinusoidal generator 23 and the impulse generator 24 are controlled by means of respective control wires by the processor 18 to enable varying both the characteristics of the sinusoidal signals and of the impulses.

Moreover, both the sinusoidal generator 23 and the impulse generator 24 are connected, by means of respective connections, to the phase comparator 14 and are able to transmit the respective signals to the comparator 14 itself.

The coupling device 15, known in itself, for instance constituted by a directional coupler or by an optical circulator, is able to collect the modulated optical signal coming from the multiplier 19 and to send it to the optical fibre 50 through the first termination.

The coupling device 15 is also able to collect the signals reflected back by the reflecting termination 51 and to send them, through a corresponding optical connection, to the optical receiver 16.

The optical receiver 16, of a known kind, has its input connected to the coupling device 15 and the output connected to the phase comparator 14 and it is able to detect the signals reflected back and to convert them into electrical signals able to be measured by the phase comparator 14.

The phase comparator 14, of a known kind, is able to measure the phase difference between the signal coming from the sinusoidal generator 23 and the one received by the optical receiver 16 through the fibre segment 50.

5 In particular, the phase comparator 14 is able to measure the phase difference between the continuous sinusoidal signal, generated by the sinusoidal generator 23, and the pulsed sinusoidal signal reflected back, received by the optical receiver 16 and to transmit such information, through a
10 corresponding connection, to the processor 18.

The processor 18, of a known kind, is able, on the basis of programs developed during the design of the apparatus 10, to control the different devices of the instrument 10, and in particular the optical source 11, the impulse generator 24,
15 the sinusoidal generator 23, the phase comparator 14 and the optical receiver 16 and to calculate and display the results of the measurements of the phase difference and group delay as a function of wavelength, based on the information from the phase comparator 14.

20 In particular, the processor 18 is able to adjust the duration and repetition frequency of the pulses generated by the pulse generator 24 on the basis of the characteristics of the fibre segment 50 being measured, such as length, presence of any intermediate connectors between the first termination
25 and the reflecting termination 51, etc.

The duration of the impulses (Fig. 2), for instance, is determined by the processor 18 (Fig.1, Fig.2) in such a way that it is no greater than twice the time of propagation of the pulses themselves in the fibre segment 50 being measured.

30 In the same way, the periodicity or repetition period of the impulses, for instance, is determined by the processor 18 in such a way that it is no less than 4 times the propagation time between the two ends in the fibre segment 50 being measured.

The conditions indicated above for the duration of the impulses and the repetition period of the impulses themselves are, as the person skilled in the art will readily comprehend, such as to allow the phase comparator 14 to
5 selectively measure the phase difference between the sinusoidal signal generated by the sinusoidal generator 23 and the sinusoidal signal reflected by the reflecting termination 51.

The processor 18 is also able to inhibit the operation
10 of the phase comparator 14, by means of the respective control connection, during the reflections from all optical connectors (including the connector at the first termination) present in the fibre segment 50 being measured. This inhibition, in particular, is effected in synchrony with the
15 impulses generated by the impulse generator 24 thanks to the connection between the pulse generator 24 itself and the phase comparator 14.

The processor 18 is also able to control the optical receiver 16, by means of the respective control connection,
20 adjusting some operating parameters such as gain, bandwidth, etc., according to the characteristics of the signals received by the optical receiver 16 itself.

The operation of the apparatus 10 according to the invention is as follows.

25 The modulated optical signal, generated by means of the combination of the signals coming from the optical source 11 and of the signal generator 12 (Fig. 2) is sent to the first end of the fibre 50 through the coupling device 15 and propagates to the opposite end of the fibre where it is
30 reflected by the reflecting termination 51 and returns to the coupling device 15.

The coupling device 15 sends the optical signal reflected by the reflecting termination 51 to the optical receiver 16, where it is converted into an electrical signal and

transmitted to the phase comparator 14 for the measurement of the phase difference between the sinusoidal signal generated locally by the sinusoidal generator 23 and the one reflected by the reflecting termination 51.

5 The phase shift between the two sinusoidal signals is proportional, as is well known, to the group delay of the fibre 50 at the working wavelength of the optical source 11 and, therefore, by repeating the operations described above with a determined number of optical signals of various
10 wavelengths it is possible to calculate, in a known manner, by means of the processor 18, the chromatic dispersion CD of the fibre segment 50.

Thanks to a first characteristic of the present invention, the apparatus or instrument 10 allows ^{measured} ~~to~~ certifying
15 or measure the chromatic dispersion CD of a fibre segment 50 accessing a single end of the fibre 50 itself. This considerably simplifies and abbreviates the measuring procedure.

Moreover, the measurements can be performed, at least in the
20 case in which the fibre 50 is terminated at the second end with a not-angled connector, by a single operator instead of two as is the case with known instruments.

According to an additional characteristic of the present invention, the reference signal for measuring the phase
25 difference is available inside the instrument and need not be obtained from a GPS receiver as in the known case taken as a reference.

The invention was described taking as reference impulse modulation signals, variable in amplitude in sinusoidal
30 fashion, but, as a person versed in the art will readily comprehend, the amplitude variations of the impulse signals can have any shape, for instance triangular or square, as long as they are such as to allow a phase shift measurement between the generated signal and the reflected signal.

Obvious modifications or variations are possible to the above description, in the dimensions, shapes, materials, components, circuit elements, connections and contacts, as well as in the details of the circuitry and of the
5 illustrated construction and of the method of operation, without thereby departing from the spirit of the invention as specified in the claims that follow.

Insert "A"

~~Claims~~

1. Apparatus (10) for measuring the chromatic dispersion (CD) of an optical fibre (50), comprising:

which comprises

an optical source (21) able to generate optical signals at variable wavelength;

a signal generator (22) able to generate modulation signals;

a modulator (23) able to generate modulated optical signals on the basis of said optical signals and of said modulation signals; and

a coupler (15) able to send said modulated optical signals to a first end of said fibre (50). *According to the invention, the characterised in that*

said signal generator (22) comprises means able to generate impulsive electrical signals having variable amplitude, and duration and periodicity determined according to the characteristics of said fibre (50).

said fibre (50) comprises in correspondence with a second end a reflecting element (51) able to reflect said modulated optical signals and to generate reflected optical signals having a reflected modulation component; and

a comparison means (14, 16, 18) associated to said first end of said fibre (50) and able to measure the phase difference between said modulation signals and said reflected modulation component.

2. Apparatus (10) as claimed in claim 1 characterised in that said coupler (15) comprises means able to receive said reflected optical signals; and

said comparison means (14, 16) comprises an optical receiver (15) connected to said coupler (15) and able to convert said reflected optical signals into electrical signals representative of said reflected modulation component; and

¹¹
~~A~~ phase comparator ^{of the comparison means is} (14) connected to ~~said~~ signal generator (12) and to ~~said~~ optical receiver (16) and able to generate an electrical signal representative of ~~said~~ phase difference.

5 ~~3. Apparatus as claimed in claim 1 or 2 characterised by~~
~~Control means (18) associated respectively to said optical source (11) and to said signal generator (12) and able selectively to control the wavelength of said optical signals and the characteristics of said modulation signals.~~

10 ~~4. Apparatus as claimed in claim 3 characterised in that said~~
~~the control means (18) comprise~~

~~computing means (18) able to calculate the chromatic dispersion (CD) of said optical fibre (50) on the basis of the phase difference measured as the wavelength of said optical signal varies.~~

15 ~~5. Method for measuring the chromatic dispersion (CD) of an optical fibre (50) characterised by the steps of~~

~~generating optical signals (11) at variable wavelength;~~

~~generating modulation signals (12) shaped by impulse electrical signals having predetermined phase, variable amplitude, duration and periodicity determined according to the characteristics of said fibre;~~

~~modulating said optical signals (19) with said modulation signals;~~

25 ~~sending the optical signals modulated with said modulation signals to a first end of said fibre (50);~~

~~reflecting at a second end of said fibre (51) said modulated optical signals in such a way as to obtain reflected optical signals having a reflected modulation component; and~~

30 ~~measuring in correspondence with said first end the phase difference between said modulation signal and said reflected modulation component.~~

The method can comprise the
~~Method as claimed in claim 5 characterised by the~~
additional step of ;
calculating (18) the chromatic dispersion (CD) of said
optical fibre (50) on the basis of the phase difference
5 measured as ~~said~~ *the* wavelength of ~~said~~ *the* optical signals varies.